

810-5, Rev. D; Vol. I  
TCI-10, Rev. G

DSN/Flight Project  
Interface Design

---

TCI-10, Rev. G  
DSN Telecommunications Interfaces  
70 Meter Antenna Subnet

January 15, 1997

---

Prepared by:

*S.D. Slobin*

---

S. D. Slobin  
System Cognizant Development Engineer

Approved by:

*A.J. Freiley*

---

A. J. Freiley  
RF System Engineer

Released by:

*George E. Shultz*

---

G. E. Shultz  
DSN Document Release

## ***Contents***

| <u>Paragraph</u> |   | <u>Page</u> |
|------------------|---|-------------|
| 1.               | Introduction .....                                | 4           |
| 1.1              | Purpose .....                                     | 4           |
| 1.2              | Scope .....                                       | 4           |
| 2.               | General Information .....                         | 4           |
| 2.1              | 70-m Diameter Antennas (DSS 14, 43, and 63) ..... | 4           |
| 2.2              | Telecommunications Parameters .....               | 4           |
| 2.3              | Arraying .....                                    | 6           |

## ***Appendices***

| <u>Appendix</u> |  | <u>Page</u> |
|-----------------|--|-------------|
| A               | Equations for Curves in Figures 1–2 and 5–11 ..... | 27          |

## ***Tables***

| <u>Table</u> |   | <u>Page</u> |
|--------------|---|-------------|
| 1            | S-band Transmit Characteristics .....                       | 7           |
| 2            | L-, S-, and X-band Receive Characteristics .....            | 9           |
| 3            | DSS 14 Eastern Horizon S-band $T_{OP}$ with SPD Cone .....  | 13          |
| 4            | DSS 14 Western Horizon S-band $T_{OP}$ with SPD Cone .....  | 14          |
| 5            | DSS 43 Eastern Horizon S-band $T_{OP}$ with Ultracone ..... | 15          |
| 6            | DSS 43 Western Horizon S-band $T_{OP}$ with Ultracone ..... | 16          |
| 7            | DSS 63 Eastern Horizon S-band $T_{OP}$ with SPD Cone .....  | 17          |
| 8            | DSS 63 Western Horizon S-band $T_{OP}$ with SPD Cone .....  | 18          |
| 9            | Gain Reduction Due to Wind Loading, 70-m Antenna .....      | 19          |
| 10           | Recommended Minimum Operating Carrier Signal Levels .....   | 19          |

## ***Illustrations***

| <b><u>Figure</u></b> |  | <b><u>Page</u></b> |
|----------------------|--|--------------------|
| 1                    | L-band System Noise Temperature, All Stations .....                        | 20                 |
| 2                    | S-band System Noise Temperature, DSS 14, LNA-1, Nondiplexed.....           | 20                 |
| 3                    | Eastern Horizon S-band System Noise Temperature at 6° Elevation Angle..... | 21                 |
| 4                    | Western Horizon S-band System Noise Temperature at 6° Elevation Angle..... | 21                 |
| 5                    | X-band System Noise Temperature vs. Elevation Angle, DSS 14.....           | 22                 |
| 6                    | X-band System Noise Temperature vs. Elevation Angle, DSS 43 and 63 .....   | 22                 |
| 7                    | S-band Gain vs. Elevation Angle, All Stations .....                        | 23                 |
| 8                    | X-band Gain vs. Elevation Angle, DSS 14 .....                              | 23                 |
| 9                    | X-band Gain vs. Elevation Angle, DSS 43 .....                              | 24                 |
| 10                   | X-band Gain vs. Elevation Angle, DSS 63 .....                              | 24                 |
| 11                   | Antenna Pointing Loss vs. Pointing Error.....                              | 25                 |
| 12                   | Functional Block Diagram of Microwave and Transmitter Subsystems .....     | 26                 |

## **1. Introduction**

### **1.1 Purpose**

This module provides sufficient information concerning the performance of the DSN 70-m antennas to enable a flight project to design a telecommunications link.

### **1.2 Scope**

The discussion in this module is limited to those parameters which characterize the RF performance of the 70-m antennas, including the effects of five specific weather conditions on 70-m receiving system gain and noise temperature.

## **2. General Information**

### **2.1 70-m Diameter Antennas (DSS 14, 43, and 63)**

Three 70-m antennas form one subnet of the Deep Space Network (DSN). One antenna, Deep Space Station (DSS) 14, is located at Goldstone, California; another (DSS 43) is located near Canberra, Australia; and a third antenna (DSS 63) is located near Madrid, Spain. The precise station locations are shown in module GEO-10, *Coverage and Geometry*.

### **2.2 Telecommunications Parameters**

The significant parameters of the 70-m antennas, which influence telecommunications link design, are contained in Tables 1 and 2. Variations of gain and system temperature due to elevation angle change and pointing error are discussed below. Telecommunications performance is also affected by atmospheric and solar effects, which are detailed in modules TCI-40, *Atmospheric and Environmental Effects*, and TCI 50, *Solar Corona and Solar Wind Effects*, respectively.

The attenuation and noise-temperature effects of weather for five specific weather conditions are included so that for those specific conditions, this module may be used without reference to module TCI-40. More comprehensive and detailed S-, X-, and Ka-band weather effects models (for weather conditions up to 98% cumulative distribution) are given in module TCI-40. The weather-included system temperature and net antenna gain curves presented in this module can be used for a quick estimate of telecommunications link performance; but, for detailed design control table use, the weather models presented in TCI-40 (revisions C and later) should be used.

Antenna gain is specified at the indicated frequency ( $f_R$ ). For operation at other frequencies in the same band, the gain (dBi) scales by  $20 \log (f/f_R)$ .

The operating system temperature ( $T_{op}$ ) varies as a function of elevation angle due to changes in the path length through the atmosphere and the intrusion of the ground into the sidelobe pattern of the antenna. Figures 1–6 show the combined effects of these factors at L-, S-, and X-bands, respectively.

The plotted curves in each case represent the total operating system temperature ( $T_{op}$ ) of the antenna in a hypothetical vacuum (no atmosphere) condition, and with 0%, 50%, and 90% weather conditions, designated as cumulative distribution (CD) = 0.00, 0.50, and 0.90. A value of 0% means minimum weather effect (exceeded 100% of the time); the 90% figure means that effect which is exceeded only 10% of the time. Qualitatively, 0% corresponds to the driest condition of the atmosphere, 25% corresponds to average clear, 50% corresponds to humid or very light clouds, and 90% corresponds to very cloudy conditions - but with no rain.

The equations and parameters for these curves (and for 25% and 80% weather) are provided in Appendix A of this module. The models use a flat-earth, horizontally stratified atmosphere approximation. At S-band (2295 MHz), the clear-sky zenith noise temperatures of each antenna are different; however, their elevation-related effects (as shown in Figure 2) are considered to be similar. Weather-effect differences are small, and the same model is used for all stations. Figure 2 shows S-band noise-temperature curves for DSS 14, LNA-1, nondiplexed. Curves for other antennas and configurations can be calculated by using the differences shown in the Table 2 noise-temperature values. The L-band system temperature curve (Figure 1) is modeled from the S-band curve, so that at zenith the 25%-weather system temperature is 35 K. At X-band (8420 MHz), DSS 43 and 63 have similar weather effects, and are subsequently illustrated in the same figure (Figure 6). DSS 14 has lower weather effects and is shown separately (Figure 5).

Tables 3–8 give S-band system noise temperatures to be expected during average clear weather conditions at elevation angles near the horizon, corresponding to rise and set azimuths of spacecraft with declinations of approximately  $-15^\circ$  to  $-25^\circ$ . These data were gathered specifically to support the Galileo Mission during the 1995 through 1998 period.

Tables 3 and 4 are for rise and set azimuths at DSS 14 (Goldstone) using the S-band SPD cone (the standard S-band receiving system). Tables 5 and 6 are for rise and set azimuths at DSS 43 (Canberra) using the S-band Ultracone (an additional, very low-noise S-band receiving system located on that antenna). Two-way operation (simultaneous transmit and receive) is not possible when the Ultracone is being used for reception. The standard SPD cone at DSS 43 is still available for low-noise and diplexed operation at that station, with a somewhat higher noise temperature, as given in Table 2 and Appendix A. Tables 7 and 8 give rise and set noise temperatures for DSS 63 (Madrid). The zenith system noise temperatures for all antennas are given in Table 2. Elevation angle dependence is shown for DSS 14 in Figure 2 and referenced in Appendix A. The elevation dependence of S-band noise temperature for all antennas is considered to be similar, subject to the low-elevation differences given in Tables 3–8. Figures 3 and 4 show S-band system noise temperatures at  $6^\circ$  elevation angle for all antennas at the eastern and western horizons for the Galileo range of rise and set azimuths.

Structural deformation causes a reduction in gain when the antenna operates at an elevation angle other than the angle of peak antenna gain. The net gain of the antenna is also reduced by atmospheric attenuation, which is a function of elevation angle and weather condition. Figure 7 shows the S-band (2295 MHz) net gains for all stations as a function of elevation angle and weather

condition, including the vacuum condition. DSS 43 gain is considered to be identical, using both the SPD cone and the ultracone. Net gain means vacuum-condition gain as reduced by atmosphere attenuation. The L-band gain curve shapes should be considered identical to the S-band curve shapes, except that they are reduced in value by the difference shown in Table 2. Figures 8–10 present the X-band (8420 MHz) effective gains of the DSS-14, -43, and -63 70-m antennas, respectively, for both vacuum condition and for three specific weather conditions defined by their cumulative distributions (CD). The equations and parameters of these curves are given in Appendix A. The models use a flat-earth, horizontally-stratified atmosphere approximation.

The gain reduction at S-and X-band due to wind loading is listed in Table 9. The gain reduction at L-band due to wind loading is negligible. The table data are for structural deformation only and presume that the antenna is maintained on-point by conical scan [(CONSCAN), discussed in module TRK-10] or an equivalent process. In addition to structural deformation, wind introduces a pointing error which is related to the antenna elevation angle, the angle between the antenna and the wind (yaw), and the wind speed. Cumulative probability distributions of wind conditions are given in module TCI-40.

Figure 11 shows the effects of pointing error on effective antenna gain (pointing loss) for the S-band transmit and the L-, S-, and X-band receive frequencies. These curves are exponential approximations, based on theoretical antenna beamwidth. Data have been normalized to eliminate elevation and wind-loading effects. The equations describing the curves are provided in Appendix A.

Table 10 provides the recommended minimum operating carrier signal levels for various combinations of low-noise amplifier and receiver bandwidths. These levels are 10 dB above the receiver threshold (design point) based on the nominal system temperatures listed in Table 2.

Figure 12 shows a functional block diagram of the 70-m antenna S- and X-band microwave and transmitter subsystems (SPD and XRO systems).

## 2.3 *Arraying*

The 70-m antenna at each DSCL can be combined into an array, with any combination of 34-m antennas, for the purpose of improving telemetry performance. The performance of arrayed antennas is discussed in modules TLM-10 and TLM-30.

**Table 1. S-band Transmit Characteristics**

| Parameter                       | Value            | Remarks   |
|---------------------------------|------------------|---|
| ANTENNA                         |                  |   |
| Gain at 2115 MHz (dBi)          | 62.73 ±0.03      | At gain set elevation angle, referenced to feedhorn aperture for matched polarization; no atmosphere included |
| Transmitter waveguide loss (dB) | 0.2 ±0.02        | 400-kW transmitter output to feedhorn aperture  |
|                                 | 0.3 ±0.02        | 20-kW transmitter output to feedhorn aperture   |
| EIRP (dBm)                      | 148.5 +0.0 -1.0  | 400-kW transmitter at feedhorn aperture   |
|                                 | 135.4 +0.0 -1.0  | 20-kW transmitter at feedhorn aperture  |
| Beamwidth (deg)                 | 0.119 ±0.003     | Half-power angular width  |
| Ellipticity (dB)<br>RCP or LCP  | 2.2 (max)        | Calculated peak-to-peak voltage axial ratio   |
| Polarization                    | RCP or LCP       | One polarization at a time, remotely selected   |
| Pointing loss<br>(dB, 3-sigma)  |                  |   |
| Angular                         | See TRK-10       |   |
| CONSCAN                         | 0.03             | At S-band, using X-band CONSCAN reference set for 0.1 dB loss   |
| EXCITER AND<br>TRANSMITTER      |                  |   |
| Frequency ranges covered (MHz)  |                  |   |
| Coherent with S-band D/L        | 2110.2 to 2117.7 |   |
| Coherent with X-band D/L        | 2110.2 to 2119.8 |   |
| 1-dB bandwidth                  | 2110 to 2118     |   |

**Table 1. S-band Transmit Characteristics (cont'd)**

| Parameter   | Value                  | Remarks   |
|---|------------------------|---|
| TUNABILITY  |                        | At transmitter output frequency   |
| Resolution (Hz)   | $4.8 \times 10^{-5}$   |   |
| Minimum ramp rate (Hz/s)  | $4.8 \times 10^{-16}$  | (Calculation capability of controller)  |
| Maximum ramp rate (Hz/s)  | $4.8 \times 10^6$      |   |
| Minimum ramp or fixed frequency duration (s)  | 0.1                    |   |
| RF POWER OUTPUT (dBm) nominal   |                        | Referenced to transmitter output port.<br>Setability is limited to 0.25 dB by measurement precision |
| 20-kW power amplifier   | 73.0 +0.0/-1.0         |   |
| 400-kW power amplifier  | 86.0 +0.0/-1.0         | (See note at end of Table 1.)   |
| Power output varies across the bandwidth and may be as much as 1 dB below nominal rating.<br>Performance will also vary from tube to tube. Normal procedure is to run the tubes saturated, but unsaturated operation is also possible. The point at which saturation is achieved depends on drive power and beam voltage. The 20-kW tubes are normally saturated for power levels greater than 60 dBm (1 kW), and the 400-kW tubes are saturated above 83 dBm (200 kW). Minimum power out of the 20-kW tubes is about 53 dBm (200 W) and about 73 dBm (20 kW) for the 400-kW tubes. Efficiency of the tubes drops off rapidly below nominal rated output. |                        |   |
| STABILITY   |                        |   |
| Power (dB)<br>12 h  | $\pm 0.5$<br>$\pm 1.0$ | saturated<br>unsaturated  |
| Phase ( $\Delta f/f$ )<br>1000-s averaging  | $5 \times 10^{-15}$    | In 1-Hz bandwidth   |
| Group delay (ns)<br>12 h  | 3.3                    |   |

**Table 1. S-band Transmit Characteristics (cont'd)**

| Parameter               | Value    | Remarks                 |
|-------------------------|----------|-------------------------|
| INCIDENTAL AM (dBc)     | 60       | Below carrier           |
| SPURIOUS RADIATION (dB) |          |                         |
| 2nd harmonic            | 85       | Below carrier           |
| 3rd harmonic            | 85       | Below carrier           |
| 4th harmonic            | -140 dBm | With 20-kW transmitter  |
|                         | TBD      | With 400-kW transmitter |

Note: 400-kW power amplifier cannot be used below 10° elevation at all stations and between 300° and 360° azimuth at DSS 63.

**Table 2. L-, S-, and X-band Receive Characteristics**

| Parameter                         | Value       | Remarks  |
|-----------------------------------|-------------|--|
| ANTENNA                           |             |  |
| Gain (dBi)                        |             | Note: favorable (+) and adverse (-) tolerances with triangular PDF.  |
| L-band (1668 MHz)                 | 60.17 ±0.3  | At gain set elevation angle, referenced to low-noise amplifier input terminal (includes feedline loss) for matched polarization; no atmosphere included.       |
| S-band (2295 MHz)<br>all stations | 63.34 ±0.10 | At gain set elevation angle (approximately 45°), referenced to LNA-1 input terminal (includes feedline loss) for matched polarization; no atmosphere included. |
| X-band (8420 MHz)                 | 63.28 ±0.10 | At gain set elevation angle (approximately 45°), referenced to LNA-2 input terminal (includes feedline loss) for matched polarization; no atmosphere included. |
| DSS 14                            | 74.17 ±0.20 | At gain set elev. angle, referenced to LNA-1 or -2 input terminal (includes feedline loss) for matched polarization; no atmosphere included.                   |
| DSS 43                            | 74.10 ±0.20 |  |
| DSS 63                            | 74.28 ±0.20 |  |

**Table 2. L-, S-, and X-band Receive Characteristics (cont'd)**

| Parameter                   | Value               | Remarks  |
|-----------------------------|---------------------|--|
| ANTENNA (cont'd)            |                     |  |
| Beamwidth (deg)             |                     |  |
| L-band                      | 0.18 ±0.02          | Full width at half-power points.   |
| S-band                      | 0.108 ±0.003        |  |
| X-band                      | 0.031 +0.003/-0.001 |  |
| Polarization                |                     |  |
| L-band                      | LCP                 | RCP available by changing mechanical configuration of feed.  |
| S-band                      | RCP and LCP         | Both polarizations available simultaneously.   |
| X-band                      | RCP and LCP         | Both polarizations available simultaneously.   |
| Ellipticity (dB)            |                     |  |
| L-band                      | 2.0 (max)           | Ellipticity is defined as the ratio of peak-to-trough received voltages with rotating linearly polarized source and circularly (elliptically) polarized receiving antenna. |
| S-band RCP and LCP          | 0.6 (max)           |  |
| X-band RCP and LCP          | 0.8 (max)           |  |
|                             |                     | Ellipticity (dB) = 20 log (V2/V1)  |
| Pointing loss (dB, 3-sigma) |                     |  |
| S-band angular              | See TRK-10          |  |
| CONSCAN                     | 0.03                | At S-band, using X-band CONSCAN reference set for 0.1 dB loss.   |
|                             | 0.1                 | Recommended value when using S-band CONSCAN reference.   |
| X-band angular              | See TRK-10          |  |
| CONSCAN                     | 0.1                 | Recommended value when using X-band CONSCAN reference  |

**Table 2. L-, S-, and X-band Receive Characteristics (cont'd)**

| LOW-NOISE AMPLIFIERS                   |   |  |  |
|--|---|--|--|
| Frequency ranges covered (MHz)         |   |  | Only two tracking receiver channels are available, which may be operated as two receivers with any pair or combination of L-, S-, and X-band frequencies, e.g., one S and one X. |
| L-band, 1 dB B/W                       | 1628 to 1708  |  |  |
| S-band, 1 dB B/W                       | 2270 to 2300  |  |  |
| X-band, 1 dB B/W                       | 8400 to 8500  |  |  |
| Recommended maximum signal power (dBm) | -90   |  |  |
| System noise temperature (K)           |   |  | Note: Adverse (+) and favorable (-) tolerances with triangular PDF.  |
| L-band                                 | 35 ± 2  |  | With respect to low-noise amplifier 1 or 2 input terminal for average clear sky near zenith. See Figure 1 for elevation dependency.  |
| S-band                                 |   |  | NOTE: average clear sky corresponds to 25% weather condition.  |
| LNA-1 non-diplexed                     |   |  |  |
| DSS 14 SPD cone                        | 15.2 +1.3/-0.7                                      |  | With respect to LNA input. Average clear weather, zenith. See Figure 2 for elevation dependence.   |
| DSS 43 Ultracone                       | 11.7 +1.0/-0.0                                      |  |  |
| DSS 43 SPD cone                        | 15.6 +1.4/-1.1                                      |  |  |
| DSS 63 SPD cone                        | 16.9 +1.7/-1.1                                      |  |  |
| LNA-1 diplexed                         |   |  |  |
| DSS 14 SPD cone                        | 19.5 +1.3/-0.7                                      |  |  |
| DSS 43 SPD cone                        | 19.9 +1.4/-1.1                                      |  |  |
| DSS 63 SPD cone                        | 21.2 +1.7/-1.1                                      |  |  |
| LNA-2 nondiplexed                      | add 5 ( $\pm 1$ ) to nondiplexed values shown above |  | Tolerances to be RSS'd with tolerances shown above.  |
| LNA-2 diplexed                         | add 5 ( $\pm 1$ ) to diplexed values shown above    |  | Tolerances to be RSS'd with tolerances shown above.  |

**Table 2. L-, S-, and X-band Receive Characteristics (cont'd)**

|                                     |  |   |
|-------------------------------------|--|---|
| LOW-NOISE AMPLIFIERS<br>(cont'd)    |  |   |
| X-band                              |  |   |
| LNA-1                               |  |   |
| DSS 14                              | $20.6 \pm 2$   | With respect to LNA input terminal<br>for average clear sky near zenith.<br>See Figures 5 and 6 for elevation<br>dependence.      |
| DSS 43                              | $21.0 \pm 2$   |   |
| DSS 63                              | $21.0 \pm 2$   |   |
| LNA-2                               |  |   |
| DSS 14                              | $20.6 \pm 2$   |   |
| DSS 43                              | $21.0 \pm 2$   |   |
| DSS 63                              | $21.0 \pm 2$   |   |
| REFERENCE CHANNEL<br>NOISE B/W (Hz) | $1 \pm 10\%$<br>$3 \pm 10\%$<br>$10 \pm 10\%$<br>$30 \pm 10\%$<br>$100 \pm 10\%$<br>$300 \pm 10\%$ | Effective two-sided threshold (design<br>point) noise bandwidth ( $2B_{Lo}$ )<br><br>1-Hz bandwidth is not available at<br>X-band |

**Table 3. DSS 14 Eastern Horizon S-band T<sub>OP</sub> with SPD Cone**

**Table 4. DSS 14 Western Horizon S-band T<sub>OP</sub> with SPD Cone**

| ELEV  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |  |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|
| 9.0   | 29.7 | 30.0 | 31.0 | 32.0 | 31.5 | 30.6 | 30.0 | 29.6 | 29.3 | 29.3 | 29.2 | 29.1 | 29.0 | 29.0 | 28.8 | 29.0 | 29.0 | 29.0 | 29.1 | 29.0 | 29.0 | 29.0 | 29.0 |  |  |
| 8.5   | 31.0 | 31.3 | 32.3 | 32.3 | 31.2 | 30.6 | 30.3 | 30.0 | 29.9 | 29.7 | 29.7 | 29.7 | 29.6 | 29.6 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 |  |  |
| 8.0   | 27.2 | 31.5 | 31.9 | 33.1 | 33.8 | 32.4 | 31.3 | 31.1 | 31.0 | 30.7 | 30.6 | 30.5 | 30.5 | 30.8 | 30.4 | 30.3 | 30.4 | 30.7 | 30.5 | 30.4 | 30.5 |      |      |  |  |
| 7.5   | 34.7 | 34.9 | 34.9 | 34.9 | 34.5 | 33.3 | 32.3 | 32.0 | 31.7 | 31.4 | 31.3 | 31.2 | 31.2 | 31.2 | 31.2 | 31.1 | 31.0 | 30.9 | 31.0 | 31.1 |      |      |      |  |  |
| 7.0   | 34.3 | 34.3 | 34.3 | 34.2 | 34.2 | 34.2 | 33.8 | 33.0 | 32.5 | 32.2 | 32.1 | 31.7 | 31.9 | 31.9 | 31.9 | 31.8 | 31.8 | 31.8 | 31.7 | 31.7 | 31.8 |      |      |  |  |
| 6.5   | 34.4 | 34.3 | 34.2 | 34.3 | 34.2 | 33.8 | 33.4 | 33.0 | 32.9 | 33.0 | 32.8 | 32.8 | 32.8 | 33.0 | 32.8 | 32.8 | 32.7 | 32.7 | 32.7 | 32.7 | 32.7 |      |      |  |  |
| 6.0   | 34.6 | 34.1 | 34.7 | 34.8 | 34.8 | 34.7 | 34.4 | 34.0 | 33.8 | 33.7 | 33.7 | 33.7 | 33.7 | 33.7 | 33.6 | 33.6 | 33.6 | 33.5 | 33.6 | 33.5 | 33.6 | 33.6 |      |  |  |
| AZ >> | 210  | 211  | 212  | 213  | 214  | 215  | 216  | 217  | 218  | 219  | 220  | 221  | 222  | 223  | 224  | 225  | 226  | 227  | 228  | 229  | 230  |      |      |  |  |
| ELEV  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |  |
| 9.0   | 29.0 | 28.9 | 28.9 | 28.9 | 29.1 | 29.1 | 28.9 | 29.1 | 29.4 | 28.9 | 28.8 | 28.8 | 28.8 | 28.7 | 28.8 | 28.8 | 28.7 | 28.7 | 28.8 | 28.9 | 29.0 |      |      |  |  |
| 8.5   | 29.5 | 29.4 | 29.4 | 29.4 | 29.5 | 29.7 | 29.5 | 29.5 | 29.4 | 29.3 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.5 | 29.5 | 29.5 | 29.5 |      |  |  |
| 8.0   | 30.5 | 30.3 | 30.2 | 30.2 | 30.1 | 30.2 | 30.2 | 29.9 | 30.0 | 30.1 | 30.2 | 30.2 | 30.2 | 30.1 | 30.1 | 30.1 | 30.1 | 30.1 | 30.0 | 30.1 | 30.2 | 30.2 | 30.3 |  |  |
| 7.5   | 31.1 | 31.0 | 31.0 | 31.0 | 30.9 | 30.9 | 30.9 | 31.0 | 31.0 | 30.9 | 30.6 | 30.9 | 31.1 | 31.0 | 31.0 | 31.1 | 30.9 | 30.9 | 30.9 | 30.7 | 30.5 |      |      |  |  |
| 7.0   | 31.8 | 31.8 | 31.7 | 31.7 | 31.8 | 31.8 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.6 | 31.6 | 31.6 | 31.4 | 31.6 | 31.7 | 31.7 | 31.6 | 31.7 |      |      |  |  |
| 6.5   | 32.7 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.5 | 32.5 | 32.6 | 32.6 | 32.5 | 32.5 | 32.5 | 32.6 | 32.5 | 32.5 |      |  |  |
| 6.0   | 33.6 | 33.7 | 33.6 | 33.7 | 33.9 | 33.9 | 33.8 | 33.8 | 33.9 | 33.8 | 33.8 | 33.8 | 33.8 | 33.8 | 33.7 | 33.7 | 33.7 | 33.7 | 33.7 | 33.8 | 33.8 | 33.8 |      |  |  |
| AZ >> | 230  | 231  | 232  | 233  | 234  | 235  | 236  | 237  | 238  | 239  | 240  | 241  | 242  | 243  | 244  | 245  | 246  | 247  | 248  | 249  | 250  |      |      |  |  |

**Table 5. DSS 43 Eastern Horizon S-band T<sub>OP</sub> with Ultracone**

**Table 6.** DSS 43 Western Horizon S-band  $T_{\text{OP}}$  with Ultracone

**Table 7. DSS 63 Eastern Horizon S-band T<sub>OP</sub> with SPD Cone**

**Table 8. DSS 63 Western Horizon S-band T<sub>op</sub> with SPD Cone**

**Table 9. Gain Reduction Due to Wind Loading, 70-m Antenna**

| Wind Speed |     | S-band Gain Reduction, dB* | X-band Gain Reduction, dB* |
|------------|-----|----------------------------|----------------------------|
| km/hr      | mph |                            |                            |
| 32         | 20  | Negligible                 | 0.1                        |
| 48         | 30  | Negligible                 | 0.3                        |
| 72         | 45  | 0.15                       | 1.5                        |

\* Assumes antenna is maintained on point, using CONSCAN or an equivalent. Worst case, with most adverse wind-antenna orientation.

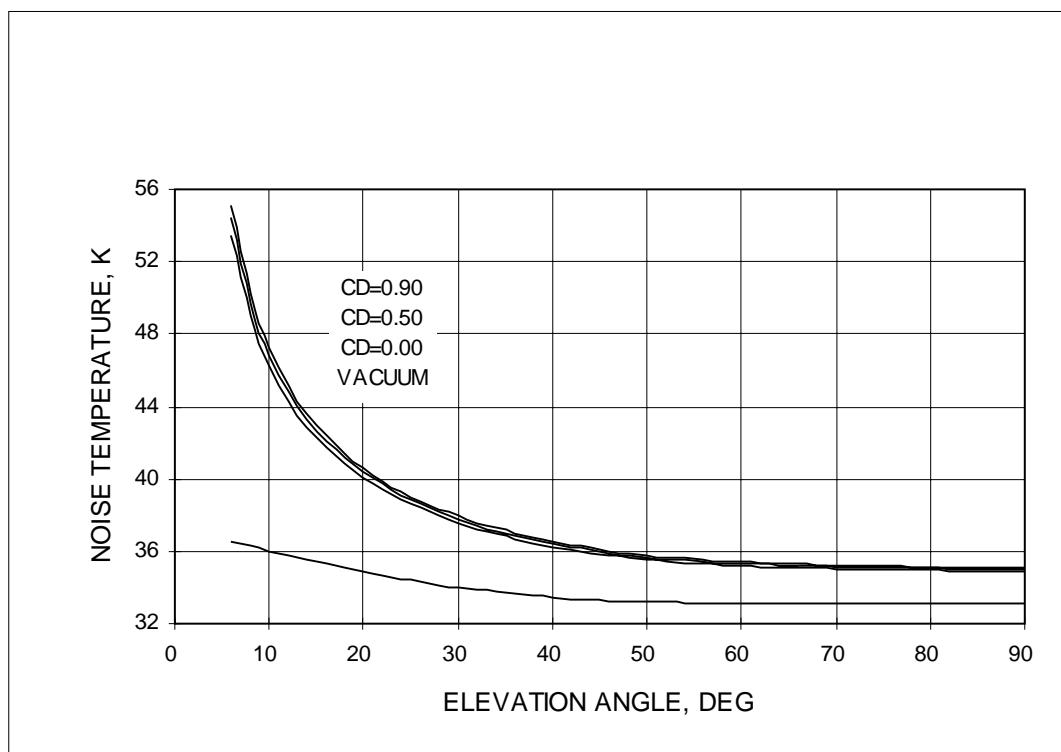
**Table 10. Recommended Minimum Operating Carrier Signal Levels**

| Reference Channel Noise Bandwidth ( $2B_{LO}$ ) | Minimum Carrier Signal Level, dBm <sup>a</sup> |              |        |        |        |        |
|---|--|--------------|--------|--------|--------|--------|
|   | 1 Hz   | 3 Hz         | 10 Hz  | 30 Hz  | 100 Hz | 300 Hz |
| L-band LNA-1 or 2                               | <sup>b</sup>                                   | -168.4       | -163.2 | -158.4 | -153.2 | -148.4 |
| S-band Ultracone, DSS43                         | <sup>b</sup>                                   | -173.2       | -167.9 | -163.2 | -157.9 | -153.2 |
| S-band LNA-1 <sup>c</sup>                       |  |              |        |        |        |        |
| diplexed  | <sup>b</sup>                                   | -170.8       | -165.6 | -160.8 | -155.6 | -150.8 |
| listen-only                                     |  | -171.9       | -166.6 | -161.9 | -156.6 | -151.9 |
| S-band LNA-2 <sup>c</sup>                       |  |              |        |        |        |        |
| diplexed  | <sup>b</sup>                                   | -169.8       | -164.6 | -159.8 | -154.6 | -149.8 |
| listen-only                                     | <sup>b</sup>                                   | -170.6       | -165.4 | -160.6 | -155.4 | -150.6 |
| X-band LNA-1 and 2                              |  |              |        |        |        |        |
| DSS 14  | N/A  | <sup>b</sup> | -165.5 | -160.7 | -155.5 | -150.7 |
| DSS 43 and 63                                   | N/A  | <sup>b</sup> | -165.4 | -160.6 | -155.4 | -150.6 |

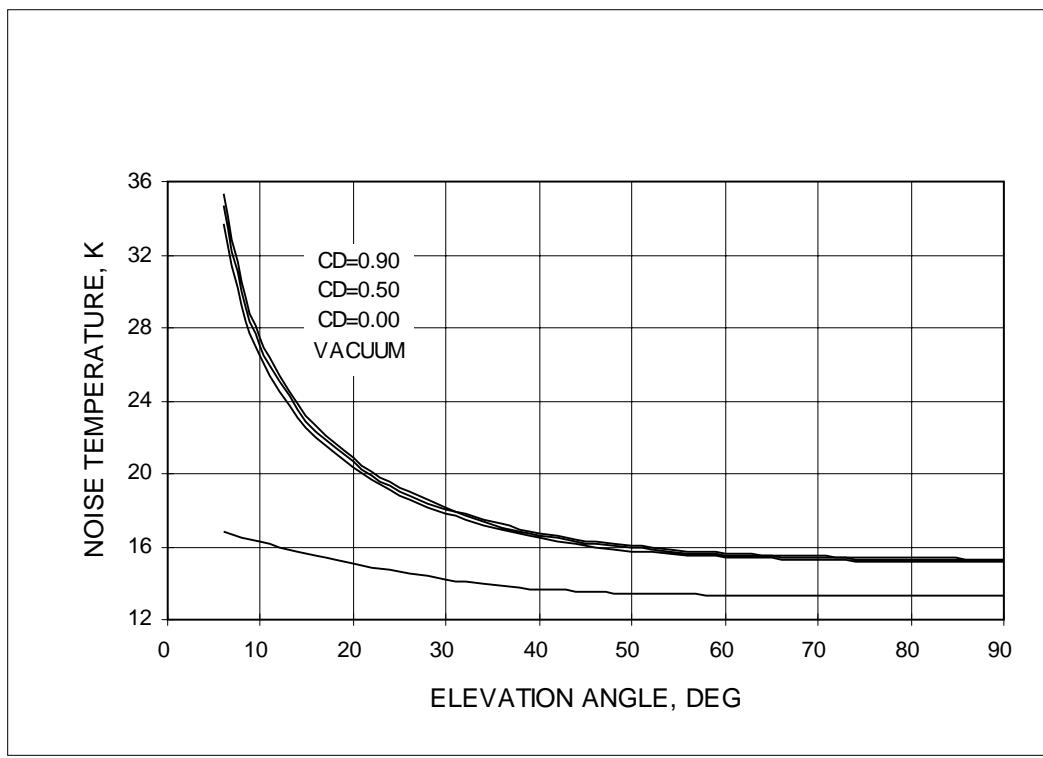
<sup>a</sup> Levels are 10 dB above RF loop design threshold, with nominal system noise temperature and nominal loop bandwidths assumed, referenced to TWM or LNA input terminals. A bandwidth given as, e.g., "10 Hz" actually means 5 Hz each side of carrier frequency, and so forth.

<sup>b</sup> Use of this bandwidth is not recommended due to phase jitter introduced into the loop bandwidth by the local oscillator (see module TRK-20).

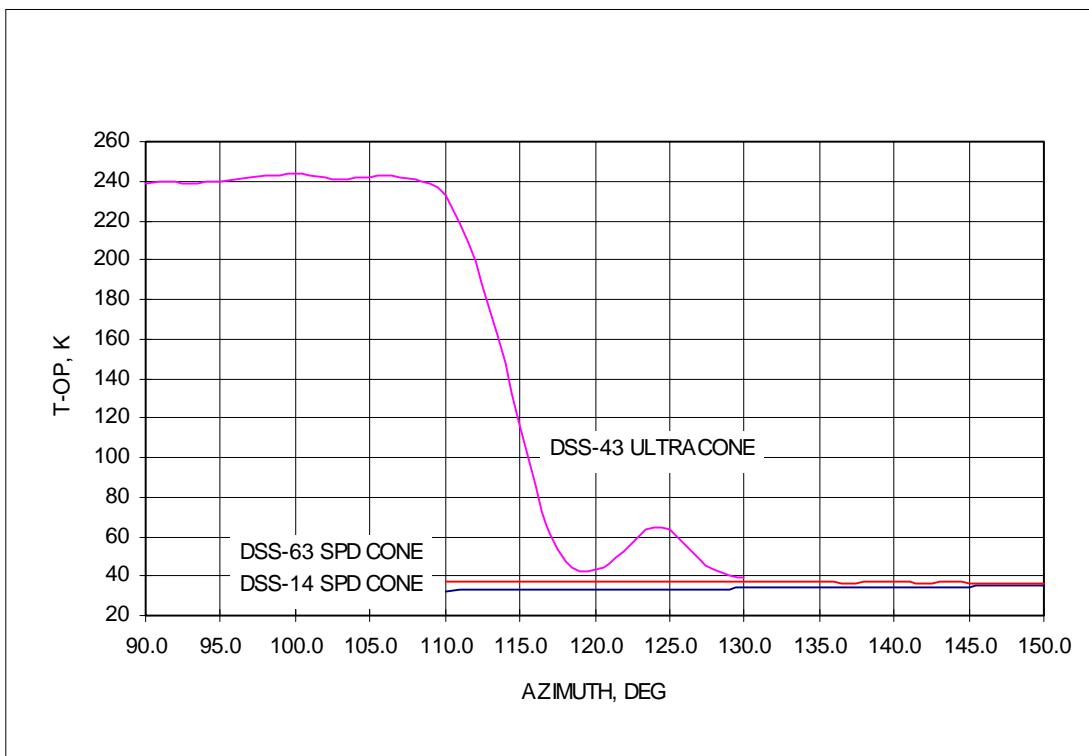
<sup>c</sup> S-band levels are calculated using the average of the noise temperature values given in Table 2.



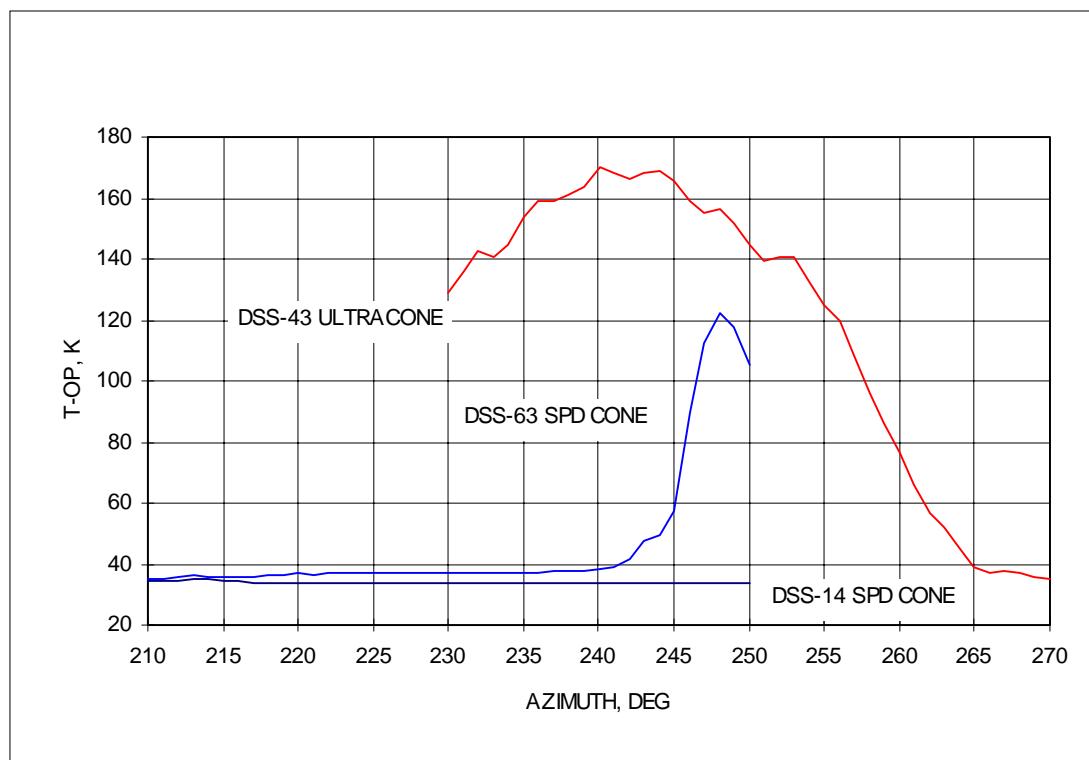
**Figure 1. L-band System Noise Temperature, All Stations**



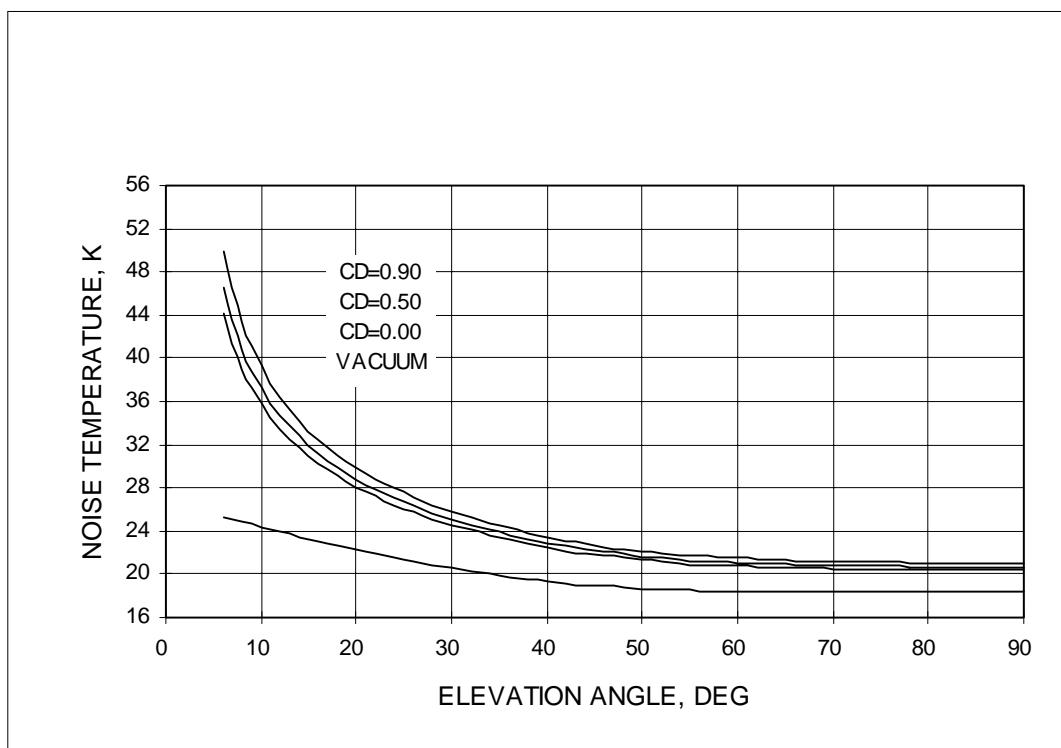
**Figure 2. S-band System Noise Temperature vs. Elevation Angle, DSS-14,  
LNA-1, Nondiplexed (See Appendix A for DSS 43 and 63)**



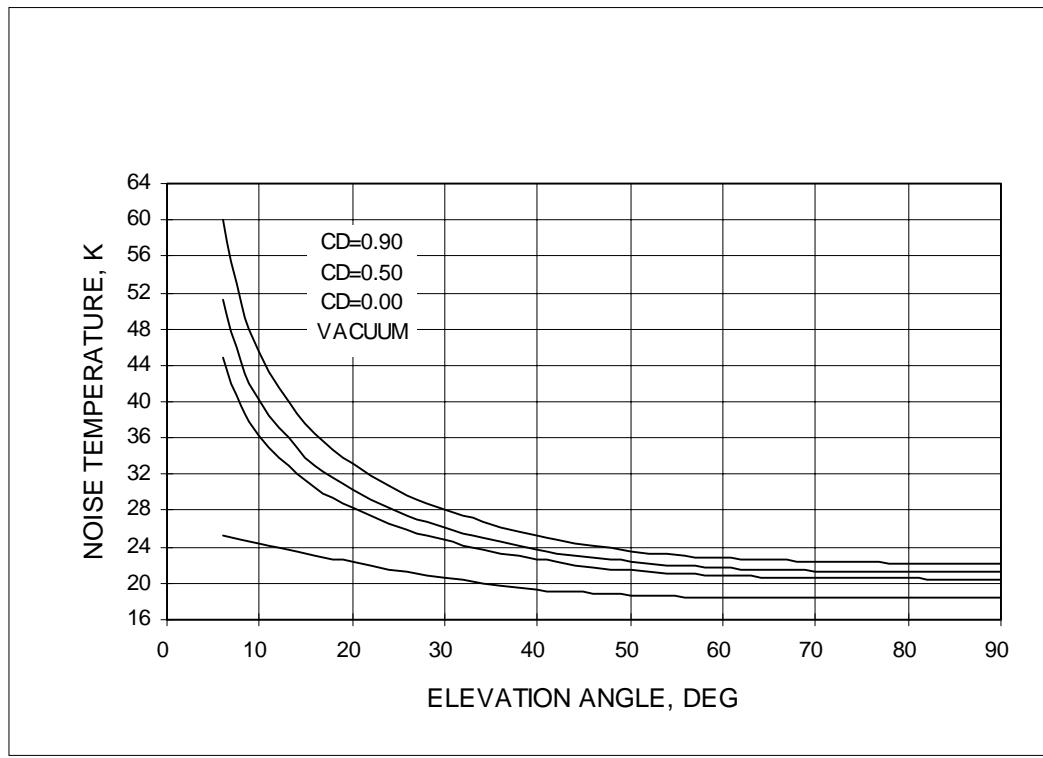
**Figure 3. Eastern Horizon S-band System Noise Temperature at 6° Elevation Angle**



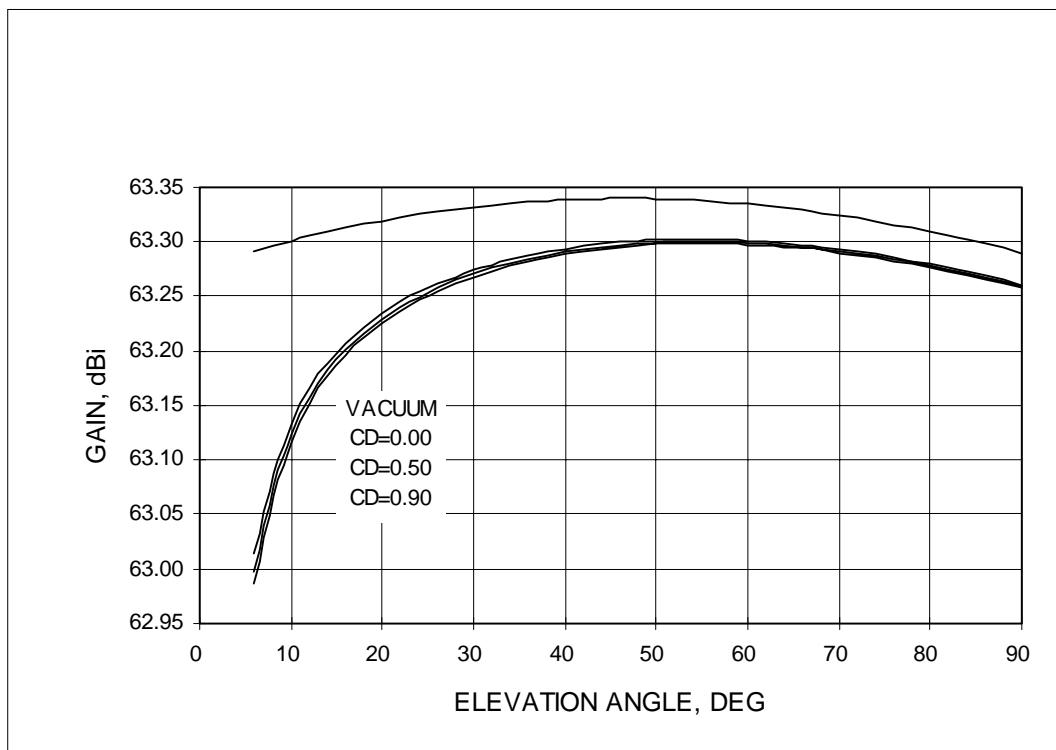
**Figure 4. Western Horizon S-band System Noise Temperature at 6° Elevation Angle**



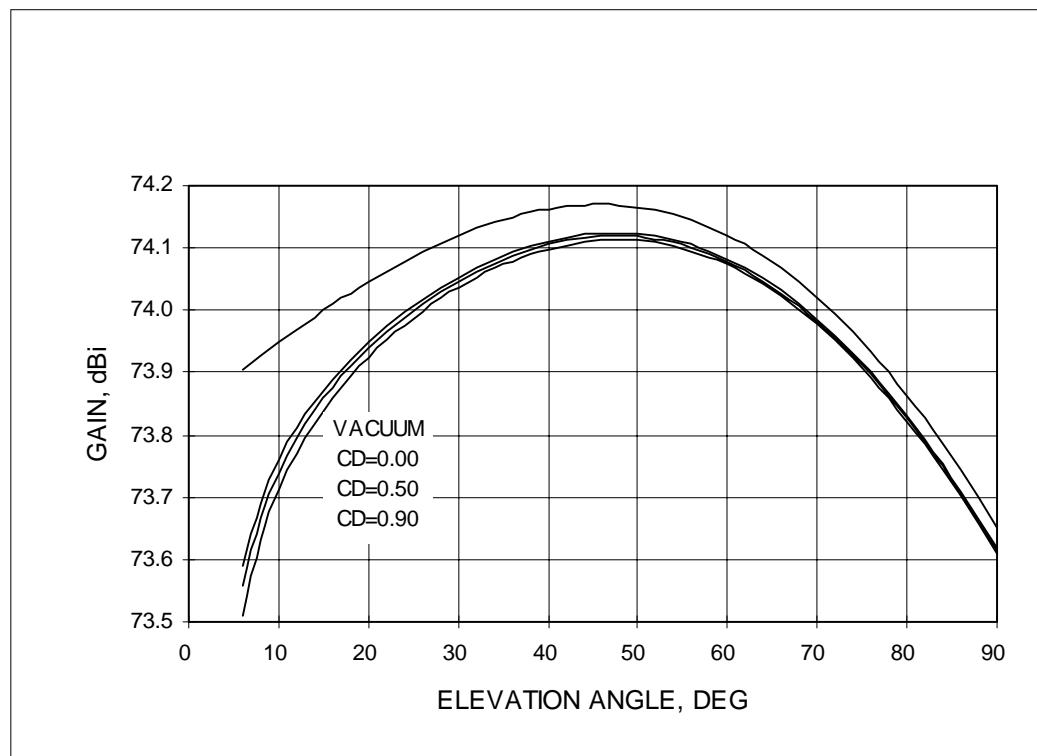
**Figure 5. X-band System Noise Temperature vs. Elevation Angle, DSS 14**



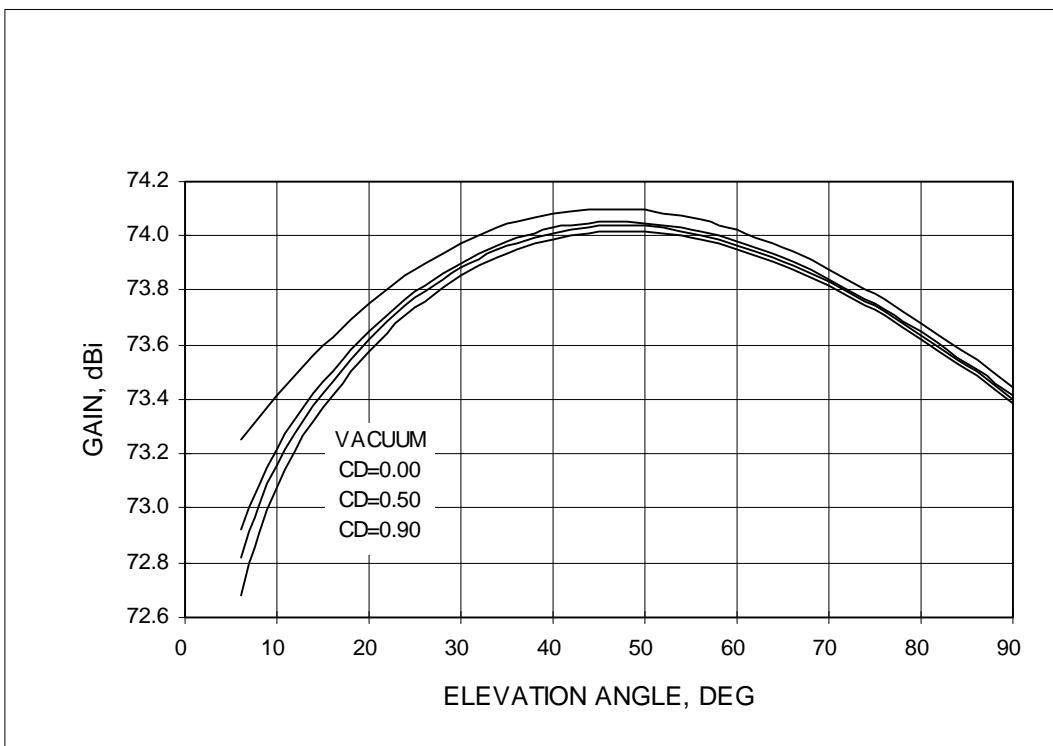
**Figure 6. X-band System Noise Temperature vs. Elevation Angle,  
DSS 43 and DSS 63**



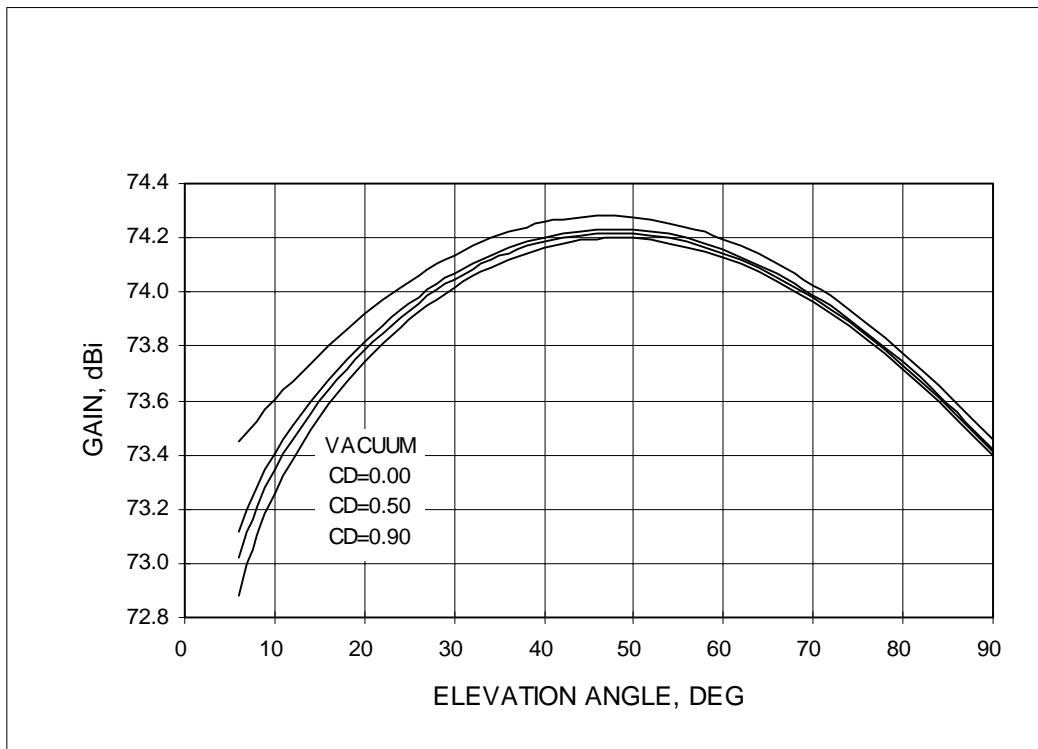
**Figure 7. S-band Gain vs. Elevation Angle, All Stations**



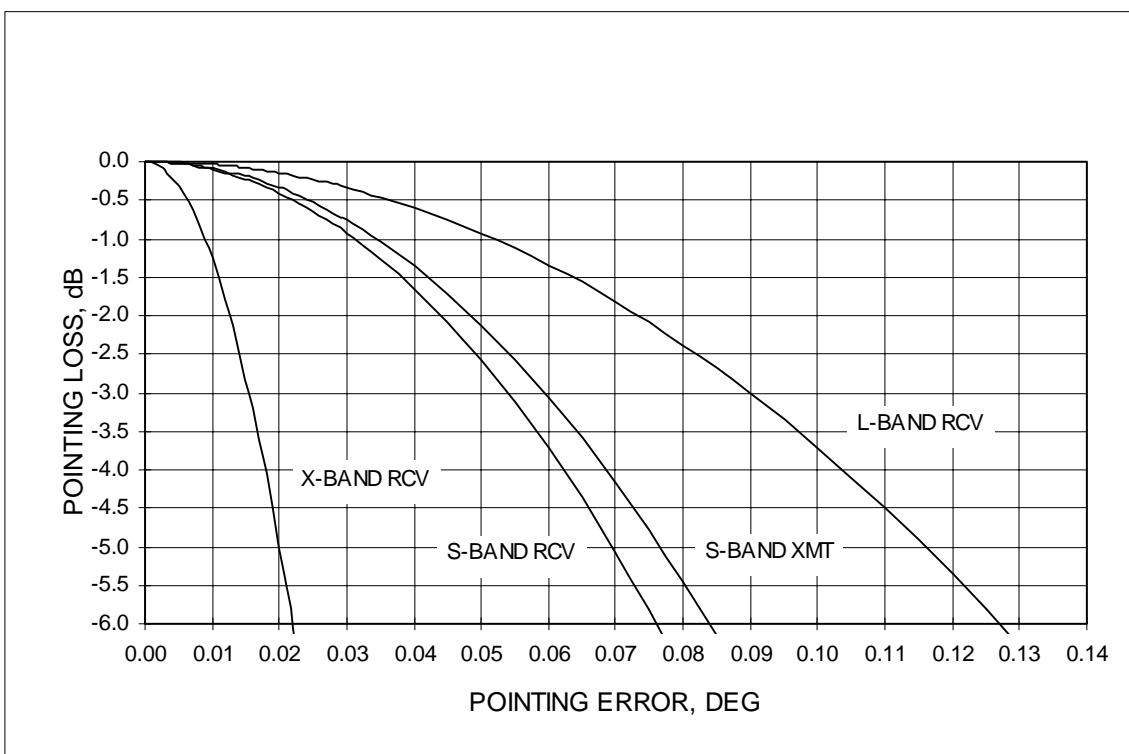
**Figure 8. X-band Gain vs. Elevation Angle, DSS 14**



**Figure 9. X-band Gain vs. Elevation Angle, DSS 43**



**Figure 10. X-band Gain vs. Elevation Angle, DSS 63**



**Figure 11. Antenna Pointing Loss vs Pointing Error**

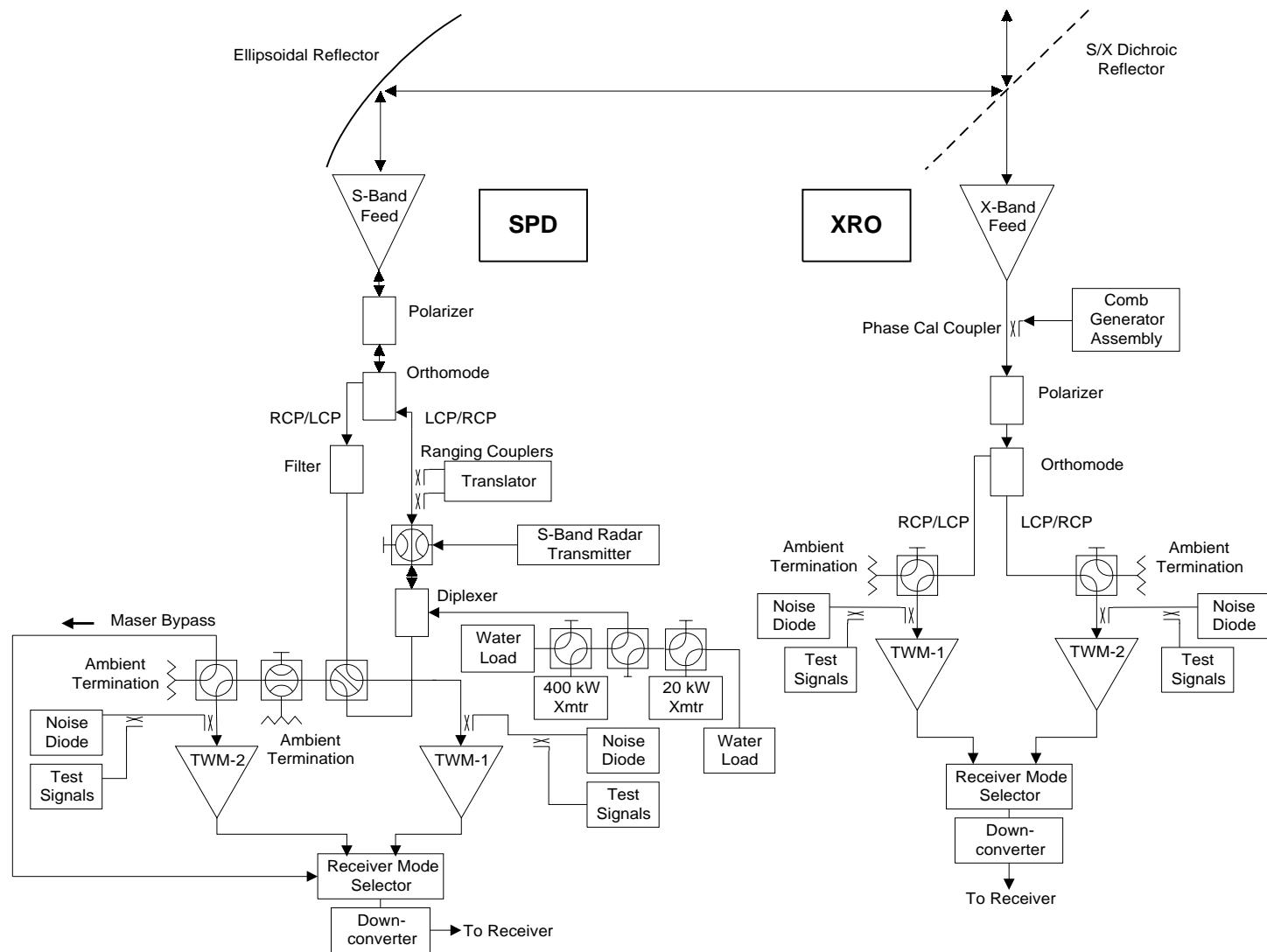


Figure 12. Functional Block Diagram of Microwave and Transmitter Subsystems

## *Appendix A*

### *Equations for Curves in Figures 1–2 and 5–11*

- Figure 1      L-band System Temperature vs. Elevation Angle  
 Figure 2      S-band System Temperature vs. Elevation Angle  
 Figures 5–6    X-band System Temperature vs. Elevation Angle.  
 Note:           Equations valid for elevation angle  $\theta \geq 6^\circ$

$$T_{op}(\theta) = T_1 + T_2 \exp[-a/(90 - \theta)] + T_z / [\sin\theta]^B \quad K$$

where  $B = 1 - 0.27A_z$  and  $A_z$  is given on page 29

| Parameter | Vacuum Component of System Noise Temperature* |                 |                  |                 |                 |              |
|-----------|---|-----------------|------------------|-----------------|-----------------|--------------|
|           | L-band  | S-band          |                  |                 |                 | X-band       |
|           | All Stations                                  | DSS 14 SPD Cone | DSS 43 Ultracone | DSS 43 SPD Cone | DSS 63 SPD Cone | All Stations |
| $T_1$ (K) | 33.11   | 13.35           | 9.78             | 13.75           | 15.05           | 18.39        |
| $T_2$ (K) | 101.95  | 101.95          | 101.95           | 101.95          | 101.95          | 122.43       |
| a (deg)   | 285.00  | 285.00          | 285.00           | 285.00          | 285.00          | 241.50       |

\* Note: See Tables 3–8 for system noise temperatures at low elevation angles.

$T_z$  (zenith atmosphere noise above vacuum) is given by:

| Weather Condition | Atmospheric Noise Temperature, K |                    |                           |
|-------------------|----------------------------------|--------------------|---------------------------|
|                   | L- and S-band                    |                    | X-band                    |
|                   | All Stations<br>(Figs. 1 and 2)  | DSS 14<br>(Fig. 5) | DSS 43 and 63<br>(Fig. 6) |
| Vacuum            | 0.000                            | 0.000              | 0.000                     |
| 0%                | 1.798                            | 2.006              | 2.097                     |
| 25%               | 1.848                            | 2.170              | 2.534                     |
| 50%               | 1.903                            | 2.276              | 2.794                     |
| 80%               | 1.965                            | 2.458              | 3.273                     |
| 90%               | 1.984                            | 2.633              | 3.775                     |

Figure 7      S-band Gain vs. Elevation Angle

Figures 8–10    X-band Gain vs. Elevation Angle

Note:              Equation valid for elevation angle  $\theta \geq 6^\circ$

$$G(\theta) = G_0 - G_1 (\cos\gamma - \cos\theta)^2 - G_2 (\sin\gamma - \sin\theta)^2 - A_z/\sin\theta \quad \text{dBi}$$

| Parameter                | Vacuum Component of Gain |              |        |        |        |
|--------------------------|--------------------------|--------------|--------|--------|--------|
|                          | L-band                   |              | S-band | X-band |        |
|                          | All Stations             | All Stations | DSS 14 | DSS 43 | DSS 63 |
| $G_0$ (dB <sub>i</sub> ) | 60.17                    | 63.34        | 74.17  | 74.10  | 74.28  |
| $G_1$ (dB <sub>i</sub> ) | 0.088                    | 0.088        | 0.990  | 1.047  | 1.490  |
| $G_2$ (dB <sub>i</sub> ) | 0.104                    | 0.104        | 0.473  | 1.979  | 1.766  |
| $\gamma$ (deg)           | 46.27                    | 46.27        | 45.78  | 46.21  | 46.83  |

$A_z$  (zenith atmosphere attenuation above vacuum) is given by:

| Weather Condition | Atmospheric Attenuation, dB |                    |                    |
|-------------------|-----------------------------|--------------------|--------------------|
|                   | L- and S-band               | X-band             |                    |
|                   | All Stations<br>(Fig. 7)    | DSS 14<br>(Fig. 8) | DSS 43<br>(Fig. 9) |
| Vacuum            | 0.0000                      | 0.0000             | 0.0000             |
| 0%                | 0.0290                      | 0.0330             | 0.0345             |
| 25%               | 0.0298                      | 0.0352             | 0.0411             |
| 50%               | 0.0307                      | 0.0364             | 0.0448             |
| 80%               | 0.0317                      | 0.0387             | 0.0516             |
| 90%               | 0.0320                      | 0.0413             | 0.0593             |

Figure 11 S-band Transmit Gain Reduction (dB) vs. Angle off Boresight ( $\theta$ , deg)

$$\Delta G = 10 \log [\exp(-195.8 \theta^2)]$$

L-band Receive Gain Reduction (dB) vs. Angle off Boresight ( $\theta$ , deg)

$$\Delta G = 10 \log [\exp(-85.57 \theta^2)]$$

S-band Receive Gain Reduction (dB) vs. Angle off Boresight ( $\theta$ , deg)

$$\Delta G = 10 \log [\exp(-237.7 \theta^2)]$$

X-band Receive Gain Reduction (dB) vs. Angle off Boresight ( $\theta$ , deg)

$$\Delta G = 10 \log [\exp(-2885 \theta^2)]$$